

TITLE OF THE INVENTION

ONE-CHIP IMAGE PROCESSING APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

5 This application is based upon and claims the benefit of priority from the prior Japanese Patent Application No. 2003-066763, filed March 12, 2003, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

10 1. Field of the Invention

The present invention relates to an image processing apparatus, particularly to a one-chip image processor. Further, the present invention relates to an image processing apparatus for use in, for example, 15 computer graphics, computer vision, image filters, and the like.

2. Description of the Related Art

Generally, an image processing apparatus has an image processing section configured with a rasterizing section for preparing an address and a computing 20 parameter, and a computing section for performing processing in units of pixels.

Conventionally, a processor used for computer graphics requires a highly functional rasterizing 25 section for expanding an arbitrary triangle into pixels. Further, when high-level shading processing is performed for pixels, a complex computing section

having a pipeline structure or a pixel pipeline is required. An image pipeline system is described in, for example, U.S Patent 6,198,488 of Lindholm et al. In such an image pipeline system, many circuits
5 which do not require to operate when simple image processing is performed are included and latency until a processing result is output also becomes longer, which deteriorates processing efficiency.

On the other hand, a conventional image processor
10 for use in computer graphics, image filters, or the like is configured with address-generating and computing sections having remarkably simple configurations. Therefore, when complex graphics processing is performed, data is frequently written
15 into/read from a memory, which deteriorates processing efficiency.

Further, because a general versatile processor cannot utilize the parallelism of pixel processing unique to general image processing, processing
20 efficiency is worse as compared with an image-processing-exclusive processor.

FIG. 1 shows one configuration example of a conventional image processing section. This image processing section uses a Digital Differential Analyzer
25 (DDA) as a processing algorithm.

In the image processing section, a setup section 201, a DDA section 202, an expansion section 203,

a plurality of pixel processing sections 204, a memory controller 205, and an internal memory 206 are formed on the same semiconductor chip.

5 The setup section 201, the DDA section 202, and the expand section 203 perform rasterizing processing. The pixel processing sections 204 are directed for performing pixel processing, and each pixel processing section 204 includes a computing section 207.

10 FIG. 2 shows one operation example of the pixel processing section 204 in FIG. 1.

This example shows a case where eight pixel processing sections 204 are provided, and a stamp of 4×2 pixels is simultaneously processed by a pipe line of 4×2 .

15 In the pixel processing section 204 in FIG. 1, when the computing section 207 performs loop computation processing a plurality of times, a plurality of neighboring pixels are processed by a different loop configured in the path from the setup section 201 to the computing section 207, which makes control by the memory controller 205 complex.

20 U.S Patent 6,333,744 of Kirk et al discloses a graphics processing apparatus for performing processing with respect to pixels. The apparatus disclosed performs pixel processing at a texture stage and at a register combiner stage. Required data is read from a memory into the texture stage, where

25

processing appropriate for graphics is performed.

A color of a pixel is calculated using the data at the register combiner stage. At the register combiner

stage, input data and a computation type are defined to

5 the respective cascade-connected computing devices and

data streams are flowed so that the pixels are

processed. Therefore, the numbers of computing devices

and items of input data are increased so that an input

data designation method or a connection relationship

10 between the computing devices is made more flexible.

As described above, with respect to the

conventional image processing apparatus, there has not

been proposed architecture of an image processor

capable of efficiently performing image processing in

15 computer graphics, computer vision, or image filtering,

and the problem is desired to be eliminated.

BRIEF SUMMARY OF THE INVENTION

According to an aspect of the present invention,

there is provided an image processing apparatus

20 comprises a block expansion section formed in a

semiconductor chip, which handles an area to be drawn

in units of blocks each composed of a plurality of

pixels and performs expansion calculation of

information on a representative point of each block;

25 and a plurality of pixel processing sections formed in

the semiconductor chip, each of the plurality of pixel

processing sections comprises: a pixel expanding

section which receives block representative point information calculated in the block expanding section and expands information in units of pixels at least in a rectangular area from the information; and

5 a computing section which receives information expanded by the pixel expanding section and performs computation in units of pixels from the information each of the plurality of pixel processing sections 9, performs graphics processing in cooperation with the block
10 expanding section, and performs image processing independent of the block expanding section.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

FIG. 1 is a block diagram showing a configuration example of an image processing section in
15 a conventional image processing apparatus;

FIG. 2 is a diagram showing an operation example of a pixel processing section in FIG. 1;

FIG. 3 is a block diagram showing a configuration example of an image processing section used in a first
20 embodiment of an image processing apparatus according to the present invention;

FIG. 4 is a block diagram showing a configuration example of an image processing apparatus having the image processing section in FIG. 3;

25 FIG. 5 is a block diagram showing one example of an image processing system using the image processing apparatus in FIG. 4;

FIG. 6 is a block diagram showing a configuration example of a pixel processing section in FIG. 5;

FIG. 7 is a block diagram showing a configuration diagram of a pixel expanding section in FIG. 6;

5 FIG. 8 is a block diagram showing a configuration example of a computing section in FIG. 6;

FIG. 9 is a diagram showing a flow chart of the image processing section shown in FIG. 3;

10 FIG. 10 is a block diagram showing a configuration example of an image processing section used in a second embodiment of the image processing apparatus according to the present invention;

15 FIG. 11 is a block diagram showing a configuration example of a pixel processing section used in a third embodiment of the image processing apparatus according to the present invention;

FIG. 12 is a diagram showing one example of assignment of interblock processing with respect to the pixel processing section shown in FIG. 11;

20 FIG. 13 is a diagram showing another example of the assignment of interblock processing with respect to the pixel processing section shown in FIG. 11;

25 FIG. 14 is a diagram showing a flow chart of the image processing section in FIG. 3 having the pixel processing section shown in FIG. 11;

FIG. 15 is a block diagram showing a configuration example of a pixel processing section used in a fourth

embodiment of the image processing apparatus according to the present invention;

FIG. 16 is a diagram showing one example of a calculation operation of a bump environment map by the pixel processing section shown in FIG. 15;

FIG. 17 is a block diagram showing a configuration example of a pixel processing section used in a fifth embodiment of the image processing apparatus according to the present invention;

FIG. 18 is a diagram showing one example of relative addresses in zigzag scanning processing by the pixel processing section shown in FIG. 17; and

FIG. 19 is a block diagram showing an image processing apparatus according to a sixth embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Hereinafter, the present invention will be described in more detail, by way of embodiments, with reference to the drawings.

<First embodiment>

FIG. 3 shows a configuration example of an image processing section used in a first embodiment of the image processing apparatus according to the present invention.

An image processing section 30 shown in FIG. 3 includes a setup section 31, a block expanding section 32, a plurality of pixel processing sections 40,

a memory controller 34, and an internal memory 35,
which are formed on the same semiconductor chip.

An external memory may be employed in place of the
internal memory 35. The setup section 31 has

5 a function of computing an initial value or
an inclination coefficient for performing rasterization
with respect to transmitted apex information.

The block expanding section 32 has a function of
handling an area to be drawn in units of blocks each
10 composed of an appropriate number of pixels and
calculating information development (rasterizing)
with respect to a representative point of each block.
In this case, a processing algorithm is DDA, and the
block development is a higher level rasterizing.

15 FIG. 4 shows a configuration example of an image
processing apparatus 20 having the image processing
section 30 in FIG. 3.

In FIG. 4, an image input section 22, an image
output section 23, a memory interface 24, and the image
20 processing section 30 are connected to a system
interface 21.

FIG. 5 shows one example of an image processing
system using the image processing apparatus 20 in
FIG. 4.

25 A CPU 10 transmits/receives data to/from
a memory 11. The CPU 10 is connected to the image
processing apparatus 20 via a bus bridge 12. The image

processing apparatus 20 transmits/receives data to/from
an external memory 13, and is connected to a camera 1
via an input interface 14. Further, the image
processing apparatus 20 is connected to a video signal
output section 2 via a D/A converter 15. A controller
3, a DVD drive device 4, a hard disk device 5, and
a communication device 6 are connected to the bus
bridge 12 via an interface bus 16.

FIG. 6 shows a configuration example of the pixel
processing section 40 in FIG. 3.

The pixel processing section 40 includes a pixel
expanding section 50 and a computing section 60.

The pixel expanding section 50 has a function of
calculating development of data and addresses in units
of pixels at least in a rectangular area from block
representative point information calculated in the
block expanding section 32 in FIG. 3.

The computing section 60 has a function of
performing computation in units of pixels information-
expanded by the pixel expanding section 50 and
outputting data and addresses. At the time of
computation, data is transmitted to/received from the
internal memory 35 via the memory controller 34 in
FIG. 3.

FIG. 7 shows a configuration example of the pixel
expanding section 50 in FIG. 6.

In the pixel expanding section 50, a loop counter

section 51 controls counting of a multiple loop, and
a buffer address calculating section 52 calculates
a buffer address for reading data from a buffer 53 in
the pixel processing section 40. An address and
5 parameter calculating section 54 reads data from the
buffer 53, and calculates a plurality of parameters and
memory addresses required in the computing section 60
in FIG. 6.

FIG. 8 shows a configuration example of the
10 computing section 60 in FIG. 6. The computing section
60 includes a plurality of MAC (product sum
calculating) sections 611 to 614 and a final stage
section 615 of the MAC sections.

The computing section 60 uses a plurality of
15 addresses calculated in the pixel expanding section 50
shown in FIG. 7, that is four items of single
instruction multiple data (SIMD) in this example, to
read data from the internal memory 35 via the memory
controller 34 in FIG. 3. A plurality of parameters
20 calculated in the pixel expanding section 50 are given
to each MAC section 611 to 614, and a required
computation is performed. The final stage section 615
of the MAC sections does not read data from the
internal memory 35. In other words, the final stage
25 615 has an accumulator register instead of using read
data so as to perform accumulation.

Next, an operation of the image processing section

30 shown in FIG. 3 will be described. The image
processing section 30 shown in FIG. 3 selectively
performs either graphics processing performed by the
block expanding section 32 and the pixel processing
5 section 40 in a cooperation manner or image processing
performed by the pixel processing section 40
independent of the block expanding section 32.

At first, in the case where the graphics
processing is performed, the setup section 31
10 calculates an initial value or an inclination
coefficient for performing rasterization with respect
to transmitted apex information. The block expanding
section 32 calculates a representative value for each
block of the pixel amount which can be processed by
15 each pixel processing section 40 on the basis of the
information transmitted from the setup section 31.
Each pixel processing section 40 performs calculation
with respect to pixels in a block on the basis of the
representative value transmitted from the block
20 expanding section 32.

FIG. 9 shows flow chart when calculation of the
block representative value is processed by one pass in
the image processing section 30 shown in FIG. 3.

At first, in step S1, an initial value and
25 a difference of a parameter required for the processing
are calculated in the setup section 31. Next, in step
S2, a block having the size which the pixel processing

section 40 can process at one time is determined.

In addition, preparation for the processing is performed while covering an area to be processed with blocks. At this time, the number P of the pixel processing section is set to 0.

Next, in step S3, a determination is made as to whether or not an unprocessed block is present in the area to be processed. When the determination result is YES, that is, when an unprocessed block is present, the processing proceeds to step S4, where an address or parameter of the block representative point is calculated. A coefficient required for finding information of each pixel is calculated from the block representative point information, and the block representative point information and the coefficient are transmitted to the P-th pixel processing section. In step S5, the number P of the pixel processing section is incremented by 1 ($P=P+1$). When P matches the number of the pixel processing sections, the number P of the pixel processing section is reset to 0, and the processing returns to step S3.

In step S3, when the determination result is NO, that is, when an unprocessed block is not present, the processing is terminated.

On the other hand, in the case where the image processing is performed in the image processing section 30 in FIG. 3, the representative value for each block

can be previously calculated in many cases so that calculation for pixels is performed by only each pixel processing section 40 shown in FIG. 3.

Namely, the image processing section 30 in FIG. 3
5 having the above configuration configures the rasterizing section to which the processing in units of pixels is classified in a two-stage configuration, that is, by the block expanding section 32 and the pixel expanding section 50. Thereby, in the graphics
10 processing, the block expanding section 32 and the pixel expanding section 50 cooperate so that a rendering processing is performed by cooperation processing thereof. Further, in a vision processing or image processing, the pixel processing section 40
15 operates independent of the block expanding section 32 and the respective pixel processing sections 40 perform block processing so that the image processing can be efficiently performed.

On the contrary, a conventional pixel processing
20 section 204 shown in FIG. 1 performs only pixel processing in the graphics processing.

<Second embodiment>

FIG. 10 shows a configuration example of an image processing section 30a used in a second embodiment of
25 the image processing apparatus according to the present invention.

This image processing section 30a is different

from the image processing section 30 described above
with reference to FIG. 3 in that a pixel expanding
section 36 is provided instead of the block expanding
section 32, an address calculating section 80 is
5 provided in each pixel processing section 40a instead
of the pixel expanding section 50 in FIG. 3, and
selectors 37 controlled by a memory controller 34a are
added, and is identical thereto in others, so that like
numerals are denoted to portions corresponding to those
10 in FIG. 3.

Namely, when the graphics processing is performed
in the image processing section 30a in FIG. 10, a setup
section 31a calculates a parameter for use in
rasterizing in the pixel expanding section 36, and
15 the pixel expanding section 36 calculates the
coordinate of the center of gravity commonly used for
each parameter calculation of pixels to generate
a pixel representative value, and outputs one or more
pixel representative values in a rectangular area.
20 In this case, a plurality of selectors 37 are provided
at input sides of the respective pixel processing
sections 40a. The operations of the selectors 37 are
controlled at output sides of the memory controller 34a
and one pixel processing section 40a is selected so
25 that the pixel representative value is transferred.
This processing is sequentially performed with respect
to a plurality of pixel processing sections 40a.

In this case, a processing algorithm is Direct Evaluation (DE), and the block development is the pixel development.

Each pixel processing section 40a calculates
5 an address or parameter sequentially required for each transferred pixel in the address calculating section 80, and transfers the calculation result to the computing section 60. In this case, the address calculating section 80 performs address calculation of
10 at least the rectangular area in order to sequentially process a plurality of pixels in the rectangular area. The computing section 60 acquires required data from the transferred address via the memory controller 34a from the internal memory 35, and performs actual
15 computation to output the processing result.

In other words, the above processing is repeatedly performed in the address calculating section 80 and the computing section 60 while changing pixels with respect to all the pixels transferred to the pixel processing
20 section 40a. When a series of processings are terminated, the pixel data is written into the predetermined buffer in the internal memory 35. This processing is performed with respect to all the input primitives.

25 On the other hand, in the case where the image processing is performed in the image processing section 30a in FIG. 10, an individual parameter for each pixel

is not particularly required unlike the coordinate of the center of gravity or the like. Thus, the address calculation in the rectangular area can be mostly performed by the accumulator of the computing
5 section 60. Therefore, the representative value of the rectangular area is transferred from the internal memory 35 to each pixel processing section 40a, and an address or parameter of each pixel is calculated based on the representative value in the address
10 calculating section 80, and the computing section 60 performs processing of filtering or template matching, which is actual image processing, using the result.

For example, in the filtering by a kernel of 8×8 pixels, the address calculating section 80 sequentially
15 calculates a pixel address in a kernel of a target image, and gives it to the computing section 60 together with a filter coefficient. The computing section 60 reads the pixel data from the given address, and performs multiplication by the filter coefficient
20 to accumulate the result. At this time, any number of pixels for which multiplication is simultaneously performed can be used, and the number of pixels is 4 in this example.

<Third embodiment>

25 FIG. 11 shows a configuration example of a pixel processing section 40a used in a third embodiment of the image processing apparatus according to the present

invention.

This pixel processing section 40a is different from the pixel processing section 40 shown in FIG. 6 in that there is added a loop for returning an output of the computing section 60 to an input of the computing section 60 via a First-in First-out (FIFO) type buffer circuit 41, and is otherwise identical thereto.

In this manner, when the loop caused by the buffer circuit 41 is provided, a value being calculated is not required to return to the memory 35, thus computing section 60 can perform processing by a plurality of times of looping, that is, can repeatedly perform the processing. Therefore, complex processing is decomposed into a plurality of procedures so that processing can be performed quickly, even by a computing section 60 having a simple configuration, thereby reducing the circuit area of the computing section 60.

FIG. 12 shows one example of assignment of interblock processing with respect to the pixel processing section 40a shown in FIG. 11.

This example shows a case where four pixel processing sections 40a are provided, and each pixel processing section 40a processes a stamp of 4×2 pixels.

Here, a smaller stamp of $m1 \times m2$ is processed by the pixel processing section 40a. The stamp has a size

up to the number of pixels accumulated in the buffer circuit 41 of the pixel processing section 40a. The same coefficient is given from the block expanding section (DDA) to the pixel processing section 40a which belongs to the stamp. Each pixel processing section 40a interprets by adding an offset corresponding to the pixel processing section 40a itself. Therefore, the above processing can be said to be behavior directed to computer graphics (CG).

FIG. 13 shows another example of the assignment of interblock processing with respect to the pixel processing section 40a shown in FIG. 11.

This example shows a case where eight pixel processing sections 40a are provided and each pixel processing section 40a processes a stamp of 8×8 pixels by 4×2 pixels.

Here, because a larger stamp of $n \times n$ is processed by a plurality of pixel processing sections 40a, it is disadvantageous that the stamp is not filled. The pixel processing section 40a handles the pixels filled in the buffer circuit 41 of the pixel processing section 40a at one time. The same coefficient is given from the block expanding section (DDA) to the pixel processing section 40a which belongs to the stamp. Each pixel processing section 40a interprets by adding an offset corresponding to the pixel processing section 40a itself. Therefore,

the above processing can be said to be behavior directed to image processing.

FIG. 14 shows flow chart when calculation of the block representative value is processed by two passes in the image processing section 30 in FIG. 3 in the case where the assignment of interblock processing for the pixel processing section 40a in FIG. 11 is performed as shown in FIGS. 12 and 13.

First, in step S1, preparation for calculation at the first stage of the processing is performed. Next, in step S2, a determination is made as to whether or not the processing of all the pixels in a block has been terminated. When the determination result is NO, that is, when an unprocessed pixel is present, the processing proceeds to step S3, where a parameter is received from the pixel expanding section and the calculation at the first stage of the processing is performed, and the result thereof is written into the buffer. Thereafter, the processing returns to step S2. In step S2, when the determination result is YES, that is, when an unprocessed pixel is not present, the processing proceeds to step S4, where a preparation for calculation at the second stage of the processing is made. Next, in step S5, a determination is made as to whether or not the processing of all the pixels in a block has been terminated. When the determination result is NO, that is, when an unprocessed pixel is

present, the processing proceeds to step S6, where
a parameter is received from the pixel expanding
section, the calculation result at the first stage of
the processing is received from the buffer, and the
5 calculation at the second stage of the processing is
performed to be written into the memory. Thereafter,
the processing returns to step S5. In step S5, when
the determination result is YES, that is, when
an unprocessed pixel is not present, the processing is
10 terminated.

<Fourth embodiment>

FIG. 15 shows a configuration example of a pixel
processing section 40b used in a fourth embodiment of
the image processing apparatus according to the present
15 invention.

This pixel processing section 40b is different
from the pixel processing section 40a according to
the third embodiment shown in FIG. 11 in that the
calculation result of the computing section 60 is
20 returned to the pixel expanding section 50 via the
buffer circuit 42, and is identical thereto in others.

According to such a configuration, an address for
the next processing can be calculated in the pixel
expanding section 50 so that a so-called dependent
25 texture processing can be efficiently performed.

The processing performed in the pixel processing
section 40b having such a configuration includes Bumped

Environment Mapping of graphics, and the like.

FIG. 16 shows one example of a calculating operation of the Bumped Environment Mapping by the pixel processing section 40b.

5 First, a bump map is read, and calculation is performed as to an object or background in which direction is caught in the pixel. Next, an image of an environment map is read and a color of the pixel is calculated from the direction of the calculation
10 result. At this time, a read address of the environment map is dependent on the read result of the bump map. The direction calculated from the bump map is stored in the buffer to perform the processing. For example, a direction of a vector reflected by the
15 bump map is calculated at the first pass, and a color of the pixel is calculated by reading an image of the environment map from the direction of the vector at the second pass.

<Fifth embodiment>

20 FIG. 17 shows a configuration example of a pixel processing section 40c used in a fifth embodiment of the image processing apparatus according to the present invention.

25 This pixel processing section 40c is different from the pixel processing section 40b according to the fourth embodiment in that the calculation result of the computing section 60 is returned to the pixel expanding

section 50 via the buffer circuit 43 and the data of
the buffer circuit 43 based on the result of the
address calculation in the pixel expanding section 50
is read by the computing section 60, and is identical
5 thereto in others.

In other words, the buffer circuit 43 has a first
pass where data is read into the pixel expanding
section 50 and a second pass where data is read into
the computing section 60 according to the address from
10 the pixel expanding section 50.

According to such a configuration, the calculation
result of the computing section 60 is used for the
address calculation of the pixel expanding section 50
and the data of the buffer circuit 43 caused by the
15 address is read by the computing section 60, thereby
performing a more complicated processing.

The processing performed in the pixel processing
section 40c having such a configuration includes zigzag
scanning performed by encoding of color image
20 standardized encoding method (MPEG). In MPEG encoding,
zigzag scanning is performed after DCT conversion and
standardizing.

FIG. 18 shows one example of relative addresses in
the zigzag scanning processing by the pixel processing
25 section 40c.

As shown in FIGS. 17 and 18, in the zigzag
scanning, relative addresses for rearranging the order

in the pixel expanding section 50 are read from the buffer circuit 43 and the addresses are calculated in the pixel expanding section 50 so that the calculation result so far is read.

5 <Sixth embodiment>

FIG. 19 shows a configuration example when a plurality of image processing sections are provided according to a sixth embodiment of the image processing apparatus of the present invention.

10 This image processing apparatus 20a is different from the image processing apparatus 20 described above with reference to FIG. 4 in that a plurality of image processing sections 30 are connected to the system interface 21 via a bus or cross bus 25 and is identical
15 thereto in others, and therefore like numerals are denoted to portions corresponding to those in FIG. 4.

According to the image processing apparatus 20a having such a configuration, the plurality of image processing sections 30 can simultaneously perform
20 processings different from each other. For example, it is possible that graphics rendering is performed in a first image processing section (A) 30 and MPEG encoding is simultaneously performed in a second image processing section (B) 30.

25 Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to

the specific details and representative embodiments
shown and described herein. Accordingly, various
modifications may be made without departing from the
spirit or scope of the general inventive concept as
5 defined by the appended claims and their equivalents.